Plates, Slabs & Grids

• plates – horizontal plane, rigid
• slabs – thin, flat, rigid
  – extremely common in concrete
• grids – crossed beams
• see
  – bending
  – shear

Plates, Slabs & Grids

• types & spanning direction
Plates, Slabs & Grids

- loads & behavior
  - comparison with beams

Plates, Slabs & Grids

- compatibility
  - deflections same, even with stiffer side
  - stiffness $\propto \frac{EI}{L}$
  - twisting causes torsional stresses

Plates, Slabs & Grids

- supports
  - at points
  - flexible
  - continuous
**One-Way Plates**

- with uniform loads
  - like “wide” beams
  - moment / unit width
  - uniform curvature
- with point loads
  - resisted by stiffness of adjacent strips
  - more curvature in middle

**Moment Redistribution**

- total moment for ½ plate
  - value from basic equilibrium
  - because of curvature, it isn’t uniform at support
  - redistribution
    - bigger with big curvature
    - smaller with small curvature

**Moment Redistribution**

- continuous slabs & beams with uniform loading
  - joints similar to fixed ends, but can rotate
- change in moment to center = \( \frac{wL^2}{8} \)
  - \( M_{\text{max}} \) for simply supported beam
**Moment Distribution Method (b)**

- add load

**Moment Distribution Method (c)**

- release joint 2

**Moment Distribution Method (d)**

- release joint 3

**Moment Distribution Method (e)**

- exposure of final shape after cycles over initial shape
Ribbed Plates

• typical in reinforced concrete
• pans can be standard or wide

Ribbed Plates

• design them as T-beams
  – flange compression
  – stem compression
• “effective” flange width

Plate Structures

• slabs & columns
Two-Way Plates

- **support conditions**
  - columns
  - flexible (beams)
  - simple
  - continuous

Two-Way Plates

- **supported by columns**
  - $M_{\text{max}}$ at midspan of edges

Two-Way Plates

- **simply supported**
  - maximum curvature at midpoint of plate

Two-Way Plates

- **beam vs. wall supports**
  - stiffer supports, thinner slab
Two-Way Plates

- **bay proportions**
  - shorter side has bigger \( \frac{EI}{L} \)
  - ratio of longer side to shorter side > 1.5
  - acts like one-way plate

Two-Way Plates

- **moments found from tables or handbook solutions**
  - depend on support conditions

\[
\begin{array}{|c|c|c|}
\hline
\text{Ratio} & \text{Simply supported on all four sides} & \text{Fixed edges on all four sides} \\
\hline
a/b & C_a & C_b \\
\hline
1.0 & +0.0479 & +0.0479 \\
2.0 & +0.1116 & +0.1017 \\
\hline
\end{array}
\]

Design Considerations

- minimize bending (& depth)
- support conditions effective
  - continuous edge support preferred
  - fixed more than simple
- continuous surface
Design Considerations (cont’d)

• overhangs reverse curvature
• bay proportions
  – < 1:1.5
• load type
  – surface or point
• span range
  – rigid plates: 15’-60’

Reinforced Concrete Design

• economical & common
• resist lateral loads

Reinforced Concrete Design

• flat plate
  – 5”-10” thick
  – simple formwork
  – lower story heights

• flat slab
  – same as plate
  – 2 ¼” – 8” drop panels

• two-way joist
  – “waffle slab”
  – 3”-5” slab
  – 8”-24” stems
  – 6”-8” webs

• beam supported slab
  – 5”-10” slabs
  – taller story heights
Reinforced Concrete Design

- simplified frame analysis
  - strips, like continuous beams
- moments require flexural reinforcement
  - top & bottom
  - both directions of slab
  - continuous, bent or discontinuous

- one-way slabs (wide beam design)
  - approximate analysis for moment & shear coefficients
  - two or more spans
  - ~ same lengths
  - $w_u$ from combos
  - uniform loads with $L/D \leq 3$
  - $\ell_n$ is clear span ($+M$) or average of adjacent clear spans ($-M$)

- two-way slabs - Direct Design Method
  - 3 or more spans each way
  - uniform loads with $L/D \leq 3$
  - rectangular panels with long/short span $\leq 2$
  - successive spans can’t differ $> \text{longer}/3$
  - column offset no more than 10% span
Shear in Concrete

- at columns
- want to avoid stirrups
- can use shear studs or heads

Shear in Concrete

- critical section at d/2 from
  - column face, column capital or drop panel

Shear in Concrete

- at columns with waffle slabs
**Openings in Slabs**
- careful placement of holes
- shear strength reduced
- bending & deflection can increase

**Space “Frame” Behavior**
- handle uniformly distributed loads well
- bending moment
  - tension & compression “couple” with depth
  - member sizes can vary, but difficult

**Space “Frame” Behavior**
- shear at columns
- support conditions still important
  - point supports not optimal
- fabrication/construction can dominate design

**Folded Plates**
- increased bending stiffness with folding
- lateral buckling avoided
Folded Plates

- common for roofs
- edges need stiffening

Folded Plates

- State Farm Center, (Assembly Hall) University of Illinois
- Harrison & Abramovitz 1963
- Edge-supported dome spanning 400 feet wound with 614 miles of one-fifth inch steel wire

http://nisee.berkeley.edu/godden

www.library.illinois.edu